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MONDAY, JUNE 13, 1864.

The VERY REV. CHARLES GRAVES, D. D., President, in the Chair.

G. C. GARNETT, M. A., read the following paper:—

ON ARMOUR-PLATED SHIPS OF WAR.

THE first ships of war that were plated with iron were designed and constructed in America. Mr. Stephens, the designer and builder of some of the fleetest and most beautiful ships and steamers in the American marine, made, in 1845, a series of experiments at the expense of the American Government, to ascertain the resistance of iron plates to shot and shell. The result then arrived at was, *that plates less than an inch in thickness would resist the impact of any shell then known; and that a thickness of six inches of iron was impenetrable to every projectile that was brought against it, no matter how great the velocity, or how short the distance at which it was fired.* These results were duly communicated to the learned societies in both London and Paris. Here indeed they fell, as Sir Howard Douglas observes, on stony ground. In France, however, the result was different; for the powerful and energetic mind of the Emperor Napoleon was not long in perceiving the immense advantage of these results. Accordingly the French Government proposed, at the commencement of the Crimean war, that a class of vessels should be jointly constructed by the two governments: of these six were built in France, and six in England. These were of the class known as floating batteries. Ours, indeed, were not ready until the Russian war was concluded, and have never seen service, if we except the "Trusty," against whose sides we are daily trying the force of spherical and conical projectiles, and as yet without having obtained any settled result. They are, however, a class of vessels little suited for their intended purpose, being wall-sided, and presenting at both bow and stern a flat surface for shell and shot, but, as far as the English batteries are concerned, must for sea going purposes be deemed a failure.

"La Gloire" is built of wood, and is much stronger than is usual in our corvettes, or even in our frigates, being built, as Scott Russell, Esq., F. R. S., observes, on the model of the French line of battle ships, "Algesiras" and "Napoleon," each of 90 guns, whereas "La Gloire" only carries 40; her tonnage registers 3000 tons, and her actual displacement is 5000 or 6000; the dimensions are as follows:—Length, 250 feet; beam, 55; her maximum speed is 13·375 knots; and she is coated from three feet below the water line with 4½ inch good hammered iron. But perhaps the most curious circumstance connected with "La Gloire" is, that when she was building it was predicted that she would never be able to carry in a seaway her armour plating, much less her heavy ordnance.

Being constructed by Mons. Dupuis Délôme, one of the most intelligent naval architects of the age, it seemed rather surprising indeed, to some, that he should have made so gross a miscalculation; and indeed experience verified their belief, for she was found to answer when at sea all that was required of her, even in the worst weather. Yet, as Mr. Russell observes, she must not be viewed as her builder's "chef d'œuvre:" she was no doubt built to suit the capabilities of the French dockyards—an abundance of wood, and but little iron. Had her builders possessed the resources of England, the probability is, her construction would have been at least modified. The following is a true representation of this fine frigate, taken expressly for this paper, by Lieutenant Peile, R. N. R.

No doubt a great part of the stability depends on the materials of the hull being composed of the same or of different materials. In my opinion all iron is by far the most serviceable; yet I know that to this theory I have many opponents. General Sir Howard Douglas says, in support of iron bottoms :—"In spite of their horror of iron, the Admiralty ought to have discovered before this time that, *even* if the top sides of a man of war should be of wood, the bottom or water portion should be of iron; for it has been found in almost every case where one of our screw liners was driven at even the moderate speed of 10½ or 11 knots, the seams opened and the caulking escaped, and this indeed seems to be one of the strongest objections to converting old wooden vessels into demi-iron ships of war, such as the 'Royal Oak.'" From a Parliamentary return, dated 4th of May, 1863, in reply to a motion of Sir James Elphinstone, it appears that there were built, and building, eleven iron and ten wooden iron-clad ships of war, and the seven floating batteries, of which *three* have never been commissioned; and two, though sent on foreign service in a supposed efficient state, have cost the nation £3571 for repairs to the hulls, which expense indeed is not to be wondered at, when we find the "Thunderbolt," one of the batteries, *has never been* *commissioned*, though launched on the 22nd of April, 1856, yet has cost no less a sum than £1291 for repairs to the hull. *Vide* Return to the Honorable House of Commons in reply to Sir James Elphinstone, dated May 5, 1863, No. 237.

In reference to the cost of these iron-cased frigates, we find that in the return made on the motion of Captain Jervis the total cost of the "Black Prince" was £373,899, of which the engines cost £74,449, the hull and rigging, £272,729, the balance being for alterations; while for adopting Griffith's screw propeller a sum of £156 is acknowledged. The "Resistance" and "Defence" have cost £257,848, and £252,898; while the "Warrior" even exceeded these charges, large though they seem, her total cost, according to these dockyard returns, being £377,373—a sum that in "the days of old" would have been amply sufficient for two three-deckers and a 36 gun frigate.* Yet the question is not one of mere money: if the article contracted for was supplied, then there would be little cause for complaint, but in nine cases out of ten this is not the case. It is a matter of extreme difficulty to produce a ship of 400 feet in length with sufficient strength to stand heavy diagonal and transverse strains. Mr. Fairbairn, indeed, has investigated the relative strength of iron bars and plates; and he shows that the cohesive power or strength of bar iron may fairly be taken at 25 tons, or 56,000 lbs. per square inch of section; with bars of ¼ inch each of Yorkshire, Derbyshire, Shropshire, and Staffordshire iron, he obtained a mean breaking weight across the fibre of 21·350 tons per square inch. The Shropshire plates were the best, breaking under a strain of 22·826, while the rest barely averaged 19·563.

The cost of all iron vessels is greatly increased by the corrosion, or rust, of the material; to counteract this fatal tendency various means have been employed. There are two materials or paints in use in the British navy—one known as Hayes', and the other as M'Innes', composition—their object being, in company with a number of others, to limit as far as possible the tendency to "oxidation." Monsieur Jean Pierre Jouvin, Professor of Chemistry to the French Navy, has patented an invention of a somewhat novel description. It consists of laying sheets of zinc against the ship's sides, and between the hull and frame; and in case of the vessel being *already* built, coating the frame, and what portion of the hull can be reached, with a strong solution of zinc paint. The zinc sheets vary from $\frac{1}{14}$ inch to $\frac{1}{28}$ inch thick, while the ribs, keelsons, clamps, transversal bulkheads and all other parts not covered with these zinc sheets, are coated with a powerful solution of the metallic zinc paint. For the outside of the hull, however, this provision would hardly answer, therefore Mons. Jouvin coats it with composition composed of the following: Turbith mineral ($SO_3 3HgO$), mixed with Prussian blue ($3Fe\,Cy + 2Fe^2\,Cy^3$), producing by its contact with the "*alkaline chlorides*" of sea-water one of the most violent poisons known to mineral chemistry, viz., the *cyanide of mercury* ($HyCy$) in the shape of chloro-cyanide of mercury and sodium. He therefore first mixes 55 parts of turbith mineral and 45 parts Prussian blue, and composes the paint as follows:—Boiled linseed oil, 250 parts; red lead, 679 parts; and the aforesaid mixture, 100 parts; but this mixture must not be applied to the bare hull, which on the contrary must first receive a coating of zinc paint of not less than $\frac{1}{30}$ inch in thickness. I believe, of all the various compositions invented for the purpose, this of M. Jouvin to be the best.

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* Mr. Bidder, one of our most eminent engineers, has pronounced the "Warrior" in every respect a failure, save one—that she, under certain circumstances, is a fast vessel. Admiral Sir George Sartorius has also borne similar testimony—the vessel steering badly, and when she took a sheer, no action of the helm could stop her. She is also very lee-wardly, and rolled more than any line-of-battle ship.

The metal Mr. Whitworth uses in the construction of his ordnance is known as homogeneous iron, very much of the same nature as mild steel. It is chiefly composed of bars of Swedish iron, cut into short lengths, melted in crucibles, and cast into a large cylindrical ingot, which is subsequently forged under a tilt hammer into the required form. The guns are forged solid, bored out in the usual manner, and rifled uniformly throughout their length, without leaving any chamber at the breech end. The pitch in the rifling of a 12 pounder is one turn in 60 inches. Mr. Whitworth's favourite projectile is a "flat-headed"* hexagonal bolt. To give an idea of its force, it may be stated, that when it was fired at the "Alfred" target ship at Portsmouth, the gun being laid at 450 yards, the shot passed through 30 feet of water diagonally, and eight inches of oak, piercing the timber three feet below the surface of the water; when spherical shot, or long projectiles with rounded fronts, are fired in the water, they do not penetrate below the surface, but turn and come back again; the flat-fronted shot seems the best for traversing iron plates. If the round-fronted form of shot is fired against a thick wrought iron plate, it displaces the particles of the iron plate in a lateral direction, and has to overcome the great lateral resistance they offered to its passage. In the case of the flat-fronted shot the resistance is confined to the exact spot on which the flat front of the shot strikes, the resistance then becomes *direct*, and not lateral; and if the "momentum" of the shot is sufficient, it displaces the particles of the iron plate, and forms a vacuum in the shape of a round punched hole. With regard to the question of rifling the bores of guns, which seems to be generally assumed as an indispensable theory in these days, there are many opinions. Mr. Adams regards it as simply a contrivance for correcting the defects of badly constructed projectiles at a considerable waste of propelling power. If the centre of gravity of a conical shot is not placed at the junction of the major and minor axes, the resultant of the curve will be in a waved form. And as it is a mere matter of chance where the *bias* of a projectile may be in a gun, it is uncertain where the shot may fly to. The spinning motion in a great measure counteracts this; and with elongated shot, as commonly made, not only might the centre of gravity be out of the line of the central axis, but almost invariably, when made with its sides parallel, and with a conical point, it would, when placed in the gun, have the centre of gravity behind the middle of the length; therefore, on leaving the gun, it would try to turn over, to get the *heavy* end foremost, and it is in a great measure to counteract this that rifling is an advantage.

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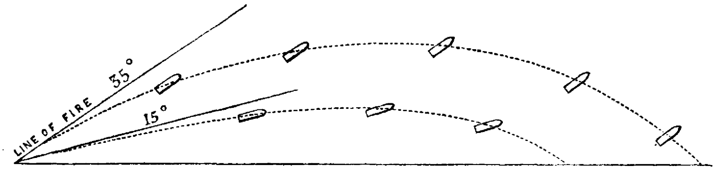
* This kind of shot is said to have been used with great success by the captain of a whaling ship, to kill seals, many years ago.

One of the chief obstacles to high angle firing (in the case of conical shot), is the fact of the major axis of the cone always keeping a constant angle in all the points of its trajectory. In the diagram given below, it will be seen that both in the case of an angle of 35° and 15° the axis (major) remains parallel to its original elevation. This is of the utmost importance in "target practice;" for if the angle became, say 45°, the axes would become parallel to the face of the target. The impact would then become oblique, and the resistance of course greater in the ratio of the axis of the cone to the axes of the common round shot; this impact, in several of its properties, is but indifferently known. The flame at the moment of concussion, now so generally observed, is the subject of great controversy. Is it the destruction of force? or is it the carbon evolved at impact by condensation of the molecules, which, mixing in the atmospheric oxygen, are fused by the heat generated by the concussion? It is true that the experiment of letting fall balls of iron from a great height into a well has had the effect of visibly raising the mercury in the thermometer; yet this heat is incapable of combustion, being at too low a temperature. Some think it to be the compression of the atmosphere to such a degree as to produce solidity, and in that state to evolve electrical properties. One thing remains certain, its appearance in almost every case where steel shot, or shell, is fired against a resisting substance of iron. Would it not be possible to measure its intensity by means of a thermetrical index attached to the target? Professor Tyndall, F. R. S., has shown that heat generated by impact increases as the square of the velocity, so that the heat of impact increases in the same ratio as velocity is augmented. Now, the velocity



imparted by gravity to a body falling through a space of 772 feet is 223 feet per second; six times this, or 1338 feet per second, would not be an inordinate velocity for a rifle ball; but if this ball was composed of lead, this velocity would raise its temperature 30°; with six times this velocity, its temperature would increase about 36 times, or 1080°, with a velocity 1338 feet per second, quite sufficient to fuse the lead if concentrated in the ball itself; but the fact is, it is divided between the target and the projectile, and in the case of the iron projectiles only one-fourth of this amount, or 320°, would represent the heat. Mr. Joule, of Manchester, has shown that if indeed all this heat in the target, after concussion, and in the projectile, and latent in the gun itself, were combined, the force represented would be sufficient to propel it back along the projected trajectory into the gun again. The concussion produced by these heavy pieces of ordnance is very great; and the lateral and longitudinal strains on the timber of the ship, such as to render the stability of the vessel a fact of the greatest importance: the vertical line being in a state of fluctuation produces an immersion, and consequent emersion, greater or less according to the stability of the vessel. Mr. Peake has shown that the height of the metacentre above the centre of gravity of displacement of the immersed portion of the body may be represented by the following formulæ* :—

$$m\,G = \frac{GF}{\sin\theta} = GF \div \sin\theta = \frac{2}{3}\int\frac{y^3 \times \sin\theta \times dx}{D} \times \frac{1}{\sin\theta} = \frac{2}{3}\int\frac{y^3 \times dx}{D};$$

from which we deduce

$$\frac{2}{3}\int\frac{y^3\,dx}{D},$$

a formula of great practical benefit in calculating the relative stability of floating bodies.

Baron Sané and M. Tupinier used the following formulæ for the relative values of the contents of the parallelepipeds of his famous 18-pounder frigates and "La Guerrière," an old 36-gun French frigate:—in "La Guerrière,"

$$x : L :: y : l :: z : h :: \sqrt[3]{N} : \sqrt[3]{P} :: \sqrt{\frac{M}{R}}\,\sqrt[3]{\frac{V}{r}};$$

$$\therefore x = L\sqrt[3]{\frac{M\,.\,r}{V\,.\,R}};\ y = l\sqrt[3]{\frac{M\,.\,r}{V\,.\,R}};\ z = h\sqrt[3]{\frac{M\,.\,R}{V\,.\,R}}.$$

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* This determines the height of the metacentric point (m) above the centre of gravity (G) of the displacement.

In 18-gun frigate, “La Gloire,”

$$x = L' \sqrt[3]{\frac{M . r'}{V' . R}}; \; y = l' \sqrt[3]{\frac{M . r'}{V' . R}}; \; z = h' \sqrt[3]{\frac{M . r'}{V' . R}},$$

and finding means for $x . y . z$. (length, breadth moulded, and depth), of immersed body, we get

$$x = \sqrt{LL' \sqrt[3]{\frac{M . r}{V . R}} \cdot \sqrt[3]{\frac{M . r'}{V' . R}}} = \sqrt{L . L' \sqrt[3]{\frac{M^2 . r . r'}{R^2 . V . V'}}}$$

$$y = \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; \sqrt{l . l' \sqrt[3]{\frac{M^2 . r . r'}{R^2 . V . V'}}};$$

$$z = \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; \sqrt{h . h' \sqrt[3]{\frac{M^2 . r . r'}{R^2 . V . V'}}};$$

$$\left.\begin{array}{l} L = \text{length on water line;} \\ l = \text{breadth, moulded;} \\ h = \text{mean depth of immersed body;} \end{array}\right\} \text{“La Guerrière.”}$$

$$\left.\begin{array}{l} x \\ y \\ z \end{array}\right\} = \text{ditto, 18-gun frigate.}$$

V and M, solids immersed.

N, content of the parallelepiped described about the immersed body.

$$\text{Ratio between these last two solids} = \frac{M}{N} = R,$$

M and R being the only variable quantities.

On the 11th of December, 1863, Sir William Armstrong's “Big Will” was fired at Shoeburyness, and with what results will be seen. This piece of ordnance weighs $22\frac{1}{2}$ tons. It is what is technically termed a built gun, being composed of eight coils of metal. It is rifled with ten grooves on the shunt principle, and the shot is made to rotate by means of ten rows of gun metal fitting into these grooves; each row contains five stems, and these stems, being made of softer metal than the grooves, do not injure it; the gun is fifteen feet in length, and the internal diameter is $13\frac{3}{10}$ inches, and the external diameter at the muzzle one foot nine inches. At ten degrees elevation, the range is no less than 4000 yards. The average weight of the shot is 600 lbs., and these are divided into three kinds—the first solid, 510 lbs.; the second hollow, for a bursting charge; and the third, a segment weighing 600 lbs. This is composed of a thin case, similar in form to that of a common shell; inside this case is built up a series of loose pieces of iron, so constructed as to form a series of rings from bottom to top; these segments number 510 pieces, each weighing six ounces; a time fuze is set on the top of the shell, which communicates with the bursting charge, fifteen pounds of powder inside the shell. After "Big Bill's" trial against the "Warrior target," the target itself underwent a strict scrutiny. The target was found fractured in every direction in radiations from the oblong aperture or rent, which was two feet long, and one foot eight inches wide in front, a couple of inches from the circular white sight, as shown in the accompanying engraving. The three-fourth inch iron backing was found torn away in long slips: the sight, indeed, when the target was struck by the shell, is said to have been very grand. The shell is said, from its enormous size, to have been distinctly seen during its entire flight of 1000 yards; and at the moment of impact volumes of smoke burst from the target, accompanied with sheets of flame.

Experiments with the "Warrior" Target.—The experiments at Shoeburyness have done much to elicit the respective merits of the various guns, and the different constructions of targets. In these trials, the breech-loader was withdrawn by Sir W. Armstrong. Excellent, no doubt, as a shell gun against wood, it does not possess that penetrating power to become a formidable antagonist against armour-plating. Originally intended to be fired with 14lbs. powder, this charge was further reduced to 12 lbs., and again reduced to 10 lbs., which is about what the weight of the gun, 60 cwt., is able to bear. The weight, and bore, and charge of the two competing 70-pounder guns were as follows:—

TABLE *a*.

Description of Gun.	Bore.	Weight.	Charge.	Bursting Charge of Shell.
Armstrong shunt, 70-pounder, . .	6·5 in.	75 cwt.	14 lbs.	2 lbs.
Whitworth 70-pr., .	5· ,,	76 ,,	12 ,,	1 lb. 14 oz.
	Range—800 yards:			REMARKS.
	1st round,.	. . .	Solid steel shot, .	*1st Round.*—Whitworth hit middle part of armour plate ("Warrior," 4½in.) and 18in. teak, and penetrated its own depth (13 in.). Rear end of shot broke off, and flew out. Shunt missed.
	2nd Round,	. . . .	Solid steel shot, .	*2nd Round.*—Whitworth, penetration as before. Shunt drove in 4½ in., burying, but not quite penetrating. Shunt missed.
	3rd Round,	. . . .	Steel shell,.	*3rd Round (Shell).*—Whitworth drove in 4½ in. Shell exploded, scattering fragments in front of the target. Shunt gun indented 2½ inches, and burst.* Pieces not found.
	Range—50 yards:			
Whitworth 70-pr. (with hexagonal shot); solid steel; 12 lbs. powder, .	. . . . .	. . . .	. . . . .	Penetrated 10 in.; head of shot split.
Armstrong shunt 70 pounder; spherical steel solid shot, weighing 34 lbs.; fired a wooden sabot, and 18 lbs. powder, .	. . . . .	. . . .	. . . . .	Rear end of shot about 3 in. below surface of plate, which was penetrated, and broke up.

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* The pieces of this shot were found next day 500 yards in front of the target, and almost in a line with the battery. This happened more than once; and it becomes evident that steel shells which divide in two parts annularly, instead of shattering into fragments, may become highly dangerous to the parties firing them, in cases where they do not penetrate.

TABLE *β*.

Description of Gun.	Bore.	Weight.	Charge.	Bursting Charge of Shell.
Armstrong shunt, 70-pounder, . .	6·5 in.	75 cwt.	14 lbs.	2 lbs.
Whitworth 70-pounder, . .	5· „	76 „	12 „	1 lb.
	Range—600 yards:			
	1st Round,	. . . .	Steel shell,	*1st Round.*—Whitworth lodged in the middle of plate, leaving rear protruding 4 inches; penetration 9½ inches, in an oblique line. Shunt gun tore face of plate, and lodged.
	2nd Round,	. . . .	Steel shot,	*2nd Round.*—Whitworth entered plate and burst, destroying the teak backing. Shunt indented target 1⅝ in. Shell exploded, and pieces retrograded in a line to the battery, to a distance of 350 yards.
	Range—50 yards:			
	1st Round,	. . . .	Steel shot,	*1st Round.*—Whitworth penetrated 6 inches. Head of shot split. Shunt gun imbedded, slightly tearing the surface of iron.
	2nd Round,	. . . .	Steel shell,	*2nd Round.*-Shunt drove in plate 10 inches, and rebounded 17 yards (not burst). Whitworth entered 4½ in., then burst, driving out teak backing, and tearing away the bolts.

The shell appears to have exploded *just* as it entered the timber backing, and it made a hole four times greater in the rear than in front. The upper plate was driven out from its supports, and the rivets broken. The bursting charge was 24 lbs., and the gun charge 70 lbs. The following is a table of the firing:—

TABLE γ.

Round.	Charge.	Elevation.	Projectile.	Range.	Lateral Deviation.
1	70 lbs.	1°.	510 lbs. solid shot.	748	1 yard left.
2	"	"	"	785	On line of fire.
3	"	"	"	789	12·5 yards left.
4	"	2°.	"	1160	1·5 yards left.
5	"	"	"	1148	On line of fire.
6	"	"	"	2400	4 yards right.
7	"	5°.	"	2338	2·5 yards left.
8	"	"	"	2308	On line of fire.
9	"	"	"	4080	2 yards right.
10	"	10°.	"	4176	On line of fire.
11	"	"	"	4187	4 yards left.
12	"	"	"	4189	2½ yards right.
13	60 lbs.	"	600 lbs. hollow shell.	1880	2 yards left.
14	"	"	"	1898	33·5 yards left.
15	"	"	"	Not taken.	
16	"	"	"	Not taken.	

Mean result of 600-pounder firing, at Shoeburyness, 18th July, 1864:—

Weight of shot (cast iron).	Charge.	Elevation.	Range.
513 lbs.	70 lbs.	20° 9′ 4″	7372 yds. 15 ft.

The above Tables have been kindly sent to me by an officer who was present.

The Marquis of Hartington, Under Secretary of War, has stated in the House of Commons that the Armstrong 600-pounder is the best gun the country has as yet got from any inventor, which has been proved by the wonderful accuracy of range and great power exhibited by this gun. Undoubtedly it is the best of *all* the Armstrong guns, their principal faults arising in a great measure from the fact of their being breech-loaders—a species of gun not to be depended on with any degree of confidence.

Whether, indeed, such a gun as the 600-pounder could be used on board the "Royal Sovereign" or "Warrior" is doubtful, the ship rolling at an angle, say of 17°, would render the weight on the vertical line of oscillation so great as to strain the ship, and affect her stability in a most dangerous degree. In such a case forts would possess a manifest advantage over ships if armed with such guns; while if seaports possessed flat-bottomed barges, propelled by a screw, carrying even one 600-pounder, any part of the coast could be easily reached, and rendered secure against an enemy, from the extreme range and power of the gun.

TABLE δ.

	Bore.		Charge of Powder.	Projectile.		Elevation.	Range.	Mean Velocity per Second.
	Diameter.	Area.		Weight.	Capacity.			
	Inches.	Inches.	lbs. ozs.	lbs. ozs.	lbs. ozs.	Degrees.	Yards.	Feet.
Rifled 9-pounder service gun, cast iron, 17 cwt.,	4·2	13·1	1 12	14 0	6 0	5	2000	not taken.
	....	....	....	....	....	10	3000	
Rifled 32-pounder service gun, cast iron, 5 cwt.,	6·41	32·2	6 0	49 0	3 12	3	1600	1220
	....	....	....	....	....	4½	2100	1016
	....	....	....	....	....	8¼	3100	930
	....	....	....	....	....	10	3600	900
Similar gun, . .	6·57	31·9	5 0	41 0	solid,	....	3700	740
Rifled 68-pounder service gun, cast iron, 95 cwt.,	8·12	51·7	6 8	90 0	7 8	10	3150	850
Rifled 32-pounder, cast iron, 95 cwt.	6·37	31·9	7 0	56 0	2 0	....	3700	955
Rifled 18-pounder, cast iron, 58 cwt.	5·29	22	6 8	34 0	1 4	....	3900	948
Smooth bore, 68-pounder service gun, cast iron, 95 cwt.,	8·12	51·7	16 0	68 0	solid,	½	340	2040
	....	....	....	....	....	1	640	1280
	....	....	....	....	....	5	1960	939
	....	....	....	....	....	14	3480	714
Armstrong breech-loader field gun,	3	7	1 6	12 0	¾	3	1200	923
	....	....	....	....	....	5	1820	900
	....	....	....	....	....	10	3030	826
Ditto, large gun, .	6	28·2	9 0	80 0	solid,	10	3900	....
Whitworth breech-loader field gun,	....	....	....	....	solid,	2	1250	Initial velocity about 1300 feet per sec.
	....	....	....	....	....	5	2300	
	....	....	....	....	....	10	780	
Ditto, large gun, weight 80 cwt.,	5·2	21	12 0	80 0	....	5	2600	ditto
	...	....	....	....	....	7	3490	
	....	....	....	....	....	10	4400	
								Initial Velocity.
Armstrong gun, 100-pounder,	....	...	12·0	111·6	solid,	....	....	1124·7
			12·0	103·8	C. shell,	....	....	1161·14

TABLE ε.

	Elevation of Gun.	Actual Range.	Paraboli Range.	Difference.	Initial Velocity in Feet per Second.
		Yds.		Yds.	
Armstrong 12-pounder gun,	7°	2480	2940	460	1080
	8°	2797	3349	552	1080
	9°	3000	3755	755	1080
Whitworth 12-pounder gun,	5°	2342	3057	715	1300
	10°	4120	6020	1900	1300
Whitworth 80-pounder un,	5°	2604	3057	453	1300
	10°	4730	6020	1290	1300

I have been informed by an officer of the Royal Horse Artillery that at 2½° the range of the Armstrong 9-pounder with 1 lb. 2 ozs. powder (charge) has a mean velocity of 955 feet per second.

The above are some of the results of the experiments made with the Armstrong and Whitworth guns, by J. A. Longridge, Esq., C. E. In all these cases the actual range is far below the range *in vacuo,* or the parabolic range.

Mr. Whitworth's shell is well known to have high penetrating power. A series of experiments are detailed in Sir James Emerson Tennent's "Story of the Guns." Its possessing *no fuse* has, indeed, been deemed a novelty; yet so far back as 1848 the French frigate "Psyche" possessed shells of a similar nature, invented by Capt. Billette, of the French navy. They were fired from the ordinary service guns of a large calibre (84-pounder). It is said to have been used with disastrous effect by the French at Mogador, in 1844, and subsequently at Algiers. If let fall from the upper to the lower deck, no accident is said to have resulted. Its combustion was, it is said, caused by the heat generated in its passage through the atmosphere, after attaining a given velocity. The following is a table of comparison between the Whitworth and Armstrong 12-pounder:—

Table ζ.

Description of Gun.*	Elevation.	Actual Range.	Initial Velocity in Feet per Second.
	Deg. Min.	Yds.	
Whitworth 12-pounder, . .	2 0	1252	1300
Armstrong 12-pounder, . .	1 15	840	1080

This would give the difference in the parabolic range, allowance being made for the inequality of level, of

	Yds.
Whitworth gun, ...	1260
Armstrong gun, ...	717

For *tensile strain* no doubt exists as to the Whitworth gun being by far the best, the metal used being *homogeneous iron,* having the toughness and ductility of wrought iron, with the hardness and tenacity of steel,—a metal which is so much used in all parts of the Continent, and for the production of which the immense factory of M. Krupp, of Essen, in Rhenish Prussia, has been designed. Mr. Whitworth's large 80 cwt. gun, with a charge of 12½ lbs., obtained an initial velocity of 1313 feet per second with a projectile weighing 80 lbs., and obtaining a range of 4400 yards. What we want for all our guns is comparative lightness and durability, combined with a moderate amount of wear. That the breech-loaders are most properly abandoned is now an admitted fact. The cost of the old 8-inch cast iron guns was about £100, while the cost of a similar breech-loader is about £800, while the initial velocity has been proved by H. M. S. "Excellent's" practice to be very inferior to that of the muzzle-loaders. The mean velocity of a 49 lb. shell, fired from a 32-pounder rifled service gun was shown to be 1120 feet per second, with a range of 1600 yards, while 826 feet per second is the mean initial velocity of a breech-loading field service gun. Guns, it must be admitted on all sides, will have an advantage over ships, as there is *no absolute* restriction to the size of the gun, though there is to the size and weight of the armour-plates of the ships. That great desideratum—"stability"—seriously affects all our iron-clads, and is a fault that can only be rectified by the loss of a great portion of that armour plate that renders them "invulnerable" (?).

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* *Vide* "Proceedings of the Institute of Civil Engineers," vol. xix., p. 442.

In the calculation of the effect of any explosive agent, due regard Mr. Longridge observes, must be given to the evolution of the permanent gases. Captain Boxer, R. A., in his valuable treatise on Artillery, computes the gases evolved from one cubic foot of gunpowder when reduced to ordinary temperature to be

Nitrogen, ...	79·4 cubic feet,
Carbonic acid, . . .	238·0 ,,

or, according to Mariotte's law, a pressure of 317·4 atmospheres. This pressure may indeed be estimated by this law, represented by the equation to an adiabatic curve—

$$p \propto \frac{1}{v^k}, \quad \text{or} \quad \frac{p}{p'} = \left(\frac{v'}{v}\right)^k.$$

Here p and p' are the pressures before and after compression; v and v', the volumes corresponding; k, the ratio of the specific heat at constant volume to that at constant pressure. In the case of air, $k = 1{\cdot}41$; and if this be the same for carbonic acid and nitrogen, the pressure after compression = 317·4 atmospheres,

= 3·367 ,,

= 22·17 tons per square inch.

In estimating the initial force of gunpowder from the velocity as ascertained by the ballistic pendulum, the usual method is that of Dr. Hutton, to find the value of n in the formula :—

$$v = 47{\cdot}4 \sqrt{\frac{nhd^2}{p+w} \cdot Log\frac{b}{a}};$$

from which we obtain

$$n = \frac{(p+w)v^2}{\overline{47{\cdot}4}|^2 hd^2 \, Log\frac{b}{a}}.$$

Now, Dr. Hutton obtained from this formula the value of $(n) = 2{\cdot}400$ atmospheres, or $15\frac{1}{2}$ tons per square inch. The result, as Mr. Longridge observes, is far from accurate: as the variation of pressure must be allowed for Mariotte's law, by adopting the true thermo-dynamical law, we have

$$n = \frac{(p+w)v^2}{\overline{47{\cdot}4}|^2 d^2 \frac{h^k(a^{1-k} - b^{1-k}}{k-1}};$$

or, applying it to Mr. Whitworth's 80-pounder, with a velocity of 1300 feet per second, a pressure of 24·58 tons per square inch.

For the different equations for the velocity of the centre of oscillation, Dr. Hutton deduced the formula—

$$\frac{biv}{pg + bi} = \frac{5{\cdot}6727\,c}{r} \sqrt{\frac{pgo + bii}{pg + bi}},$$

from which equation we get

$$v = \frac{5{\cdot}6727\,c}{bir} \sqrt{(pgo + bii) \times (pg + bi)},$$

the *true* expression *for the original velocity of the* ball, *before* it strikes the pendulum, by extracting the root of the compound factor,

$$(pgo + bii) \times (pg + bi),$$

we have

$$pg + bi \,.\, \frac{o+i}{20} \times \sqrt{o},$$

a formula *within* the $\frac{1}{100000}$ of the *true* value, from which the value can be estimated.

$$v = 5{\cdot}6727\,gc \,.\, \frac{p+b}{bir} \sqrt{o}\,.$$

The speed of most iron-clads, strange to say, is, notwithstanding the immense weight of their superincumbent armour, superior to the expectations of their designers. The greatest speed yet obtained has been that of the "Achilles;" this vessel obtained a speed at full boiler power of sixteen knots. The "Warrior" obtained a speed of $13\frac{1}{2}$ knots at a mean draught of $26\frac{1}{2}$ feet, completing her circle in eight minutes and thirty seconds, while the "Mersey" took forty minutes; one of our crack 3000 ton frigates took no less than eleven minutes and fifteen seconds to do the same. The length of the "Mersey" is 287 feet $15\frac{3}{10}$ inches, and that of the "Warrior" 383 feet $2\frac{5}{8}$ inches, which makes the "Warrior's" superiority the more remarkable, and proves that a long ship can answer the wheel as well as a short one; but in stability little can be said for vessels of the "Warrior" class. The index pendulum on the wheel standard gave a registered immersion and emersion of 15° starboard, and 12° port; and there is little doubt but that in a gale of wind the deflection will be considerably more, as when the above deflections were registered the weather was moderate. No doubt exists of the want of stability in vessels of the "Royal Sovereign" class, when the weight of the turrets is considered—130 tons, and the 5½ inch armour plate. The plan adopted, also, of transforming old wooden liners into iron cupola ships, is evidently erroneous,—the timbers of these ships not being able to withstand the strain of the increased weights; their ponderous turrets also are most objectionable,—liable, on the one hand, to get out of order, from failure or injury of the revolving machinery; and, on the other, to become rapidly choked with smoke. They oxidize to a great extent, and once strained out of the vertical line are incapable of rotation. In order to substantiate the above theories we have many American testimonies. I cannot but state a few of the most remarkable here, quoted from authentic sources.

The official reports of the commanders of the Monitors, or turret-ships, made immediately after the failure of the attack upon Fort Sumter in April, 1863, tend to show that these vessels are incapable of resisting the concentrated fire of heavy rifled ordnance. Capt. Drayton, of the "Passive," says:—"The ship was struck in quick succession in the lower part of the turret by two heavy shots, which bulged in its plates and beams, and, forcing together the rails on which the carriage of the 11-inch gun revolved, rendered it wholly useless for the remainder of the action. A little after a very heavy rifled shot struck the upper edge of the turret, broke all its eleven plates, and then, glancing upwards, struck the pilot house with such force as to send it over, open the plates, and squeeze out the top, exposing the inside of the pilot house, and rendering it useless." Capt. Rogers, of the turret-ship "Weehawken," says:—"Two or three heavy shots struck the side armour near the same place; they so broke the iron that it only remained in splintered fragments, much of which could be picked off by the hand, and the wood exposed; the iron was five inches thick. The 'Petapsco' was disabled, and the 'Nantuck' and the 'Nahant' had the iron stripped from the wood, their sides bulged in many places, and several holes in the turrets. Their armour plates on the cupolas were disconnected, and the rivets broken; and before the close of the action the 'Weehawken' had shot-holes in her sides so low down, that the water ran into the ship in streams." Such is the published American account of their iron-clad cupolas in action, and it can hardly be hoped that our turret ships are by any means capable of performing with more satisfactory results.

There seems every probability that gun-cotton will in a great measure take the place of gunpowder in iron-cased ships. In Austria it has already done so. It has, no doubt, *disadvantages*, yet from recent experiments it would seem that these were counterbalanced by certain properties of most beneficial tendency. Xyloïdine, first discovered by M. Braconnot, bears a certain affinity to the pyroxyloïdine of Professor Schœnbein; yet the former is essentially different in its composition, and has been proved to be unsuitable for firearms. John Hall Gladstone, Esq., of University College, London, has shown that by combustion with oxide of copper in a stream of oxygen, the following results were obtained:—

	Grains.
Cotton employed, ...	3·16
Carbonic acid produced, ...	5·14
Water produced, ...	2 06

These proportions are:—

Carbon, ...	44·37
Hydrogen, ...	7·24
Oxygen, ...	48·39
	100·00

Lignine, calculated from the formula, $C_{24}H_{20}O_{20}$:—

Carbon, ...	44·44
Hydrogen, ...	6·17
Oxygen, ...	49·39
	100·00

Now, this cotton, which may, observes Mr. Gladstone, be considered as a pure lignine, was steeped in nitric acid, spec. grav. 1·502, with nearly an equal bulk of strong sulphuric acid, and dried at a temperature not exceeding 212°. This composition exploded at a temperature of 370°, producing *no smoke*, and *leaving no residue*. Acetic acid at once destroys its fibre; chloroform apparently does so to a certain degree; yet, if the collodion formed is viewed microscopically, the disentegrated fibre will be seen to reunite atomically, a fact first mentioned to me by Dr. Carte, Curator of the Museum, Royal Dublin Society. Professor Barker has also informed me that he found it to explode, over a hot water bath, at 212°.* The formula $C_{24}\left\{\begin{matrix}H_{15}\\5\,NO_4\end{matrix}\right\}O_{20}$ gives carbon 26·23; hydrogen, 2·73; nitrogen, 12·75; oxygen, 58·29. If lignine be treated with nitric acid, combined with more than one equivalent of water, another compound is produced, containing a smaller amount of "nitric acid," most probably $C_{24}\left\{\begin{matrix}H_{17}\\3\,NO_4\end{matrix}\right\}O_{20}$, and, as Mr. Gladstone observes, closely resembling pyroxyline,

$$C_{24}H_{20}O_{20} + 3\left(NO_5,\ 2\,HO\right) = C_{24}\left\{\begin{matrix}H_{17}\\3\,NO_4\end{matrix}\right\}O_{20} + 9\ HO.$$

Again, if pyroxyline be treated with nitric acid containing three equivalents of water, the same compound results:—

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* This occurred at the Laboratory of Trinity College, Dublin.

$$C_{24}\left\{\begin{matrix}H_{15}\\5\,NO_4\end{matrix}\right\}O_{20}+2\left(NO_5,\,3\,HO\right)=C_{24}\left\{\begin{matrix}H_{17}\\3\,NO_4\end{matrix}\right\}O_{20}+4\left(NO_5,\,HO\right).^{*}$$

It seems the greatest care is necessary for the purification of the cotton fibres. General Baron Von Leuk has invented a system, known as the "Austrian Method." Mr. Haddon's compound, $C_{36}H_{21}\,(9\,NO_4)\,O_{30}$, is identical with that of the Austrian trinitrocellulose, $C_{12}H_7\,(3\,NO_4)\,O_{10}$; it is not of any use in the preparation of collodion, but, as Mr. Gladstone observes, it is Baron Von Leuk's gun-cotton. It has been kept unaltered for fifteen years; it is but slightly hygroscopic, and when exploded in a confined space is free from ash; its explosive temperature is 136° C. (277°F.). Baron Von Leuk treats his gun-cotton with a solution of the silicate of potash (water gas). The amount of silica set free on the cotton by the carbonic acid of the atmosphere is really of service in retarding combustion. Neither nitrous fumes nor prussic acid are among the gases evolved—the one an animal poison, the other a corrosive agent. Karolys found it to contain neither of them, but to consist of nitrogen, carbonic acid, carbonic oxide, water, a small quantity of hydrogen, and light carburetted hydrogen, and these are comparatively harmless; and it is distinctly in evidence that practically the gun is less injured by repeated charges of gun-cotton than of gunpowder, and that the men in casemates suffer less from its fumes. It is almost impossible for it to explode during the process of manufacture, since the cotton is always immersed in liquid unless during the final drying. Again, it may be submerged in water, and only used according as wanted, as it is most easily dried; its destruction in the act of combustion is complete, being wholly resolved into its component gases, and no residuum left in the gun; it produces no recoil, and does not heat the bore in the slightest degree, even under the action of repeated discharges. Scott Russell, Esq., F. R. S., has shown that the waste in gunpowder (average) is sixty-eight per cent. its own weight, only thirty-two per cent. being useful. General Von Leuk has succeeded in timing the velocity of the explosion. In his hands it possesses either one foot per second, or one foot in $\frac{1}{1000}$ of a second. The General uses it in the proportion of one-fourth to one-third weight of powder, occupying $1\frac{1}{10}$ of the length of the powder cartridge. Experiments made by the Austrian Committee show that 100 rounds could be fired of gun-cotton against thirty rounds of gunpowder: 100 rounds of gun-cotton were fired from a 6-pounder in thirty-four minutes, the gun being raised to 122° F., while in the case of gunpowder an equal number of rounds raised the gun to such a temperature that water easily evaporated. The comparative advantages of gun-cotton and gunpowder for producing high velocities may be shown from the following table :—With a Krupp's cast-steel gun (6-pounder), the ordinary charge of 30 ounces of powder produced a velocity of 1·338 feet per second; and with $13\frac{1}{2}$ ounces of gun-cotton a velocity of 1·563 feet per second was obtained; with a 12-pounder the results were—

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* See Edin. Phil. Mag., vol. xxxi., p. 519.

	Calibres.	Charge.	Velocity, feet per second.
Cotton, length,	10	15·9 oz.	1426
Powder,	13½	49 (normal powder charge)	1400
Cotton,	9	17	1402*

Captain Maury, U. S. N., says that iron-clads at Charleston have remained for several hours under fire, the decks not becoming in any way foul, from the entire absence of smoke. I think the foregoing evidence of some of the leading men of science will show that, while it possesses the disadvantage of ignition at a comparatively low temperature, it has the advantages of lightness, freedom from damp, lessening of recoil, not heating or fouling, cheapness of production, and great diminution in weight; and, to sum up all, can be submerged in water, and dried for use according as wanted; for cupola-ships it seems to be especially adapted, as it would to a great extent obviate the fouling in the turrets. Sir W. Armstrong, indeed, is of opinion that where there is no heat in the gases, there can be no projectile force: the initial velocity, however, has been proved to be greater than in the case of powder. Mr. Siemens, having considered the question, is of opinion that the greater heat imparted to the gun by gunpowder is owing to the greater amount of solid matter, which, involving the heat of the gases under a pressure of some 400 atmospheres, imparts a portion of the same by radiation to the side of the gun, while in the case of gun-cotton gases only are produced, which could only impart heat by the slower process of conduction, and leave a larger margin of heat to be developed in force by expansion; while Admiral Sir Edward Belcher supposes it to be owing to the greater rapidity of the explosion, and the absence of fouling matter, which contains and retains the heat. And it is to be hoped that the requisition of the British Association for a Government Commission to inquire into the details of this interesting subject will be granted. In the recent duel between the "Alabama" and "Kearsage," great stress has been laid on the chain armour with which her sides were in a measure protected. William Rowan, Esq., C. E., of Belfast, claims the merit of its invention; he laid, some years ago, a table of results obtained from a target composed of suspended chains, before the government. Now, no doubt, under certain circumstances it may be of benefit—for instance, as Captain Blakely observes, in the case of cast iron shot. Strange to say, it was known well in the reign of Elizabeth: a Captain John Yonge, an officer of, we are told, forty years' experience, suspended chains round

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* Professor Abel, F. R. S., has shown that the formation of trinitrocellulose may be represented by the equation :—

Cotton. Nitric Acid. Gun Cotton. Water.

$$C_6H_{10}O_5 + 3\left\{\begin{matrix} H \\ NO_2 \end{matrix}\right\} O = C_6\left\{\begin{matrix} H_7 \\ 3NO_2 \end{matrix}\right\} O_5 + 3\left.\begin{matrix} H \\ H \end{matrix}\right\} O.$$

the sides of his ships, which, he says, rendered them invulnerable to shot and shell.* Captain Winslow, U. S. N., of the "Kearsage," indeed, has replied that the chains were not so much for defence as for protecting the boilers and engines of the ship. This I can readily understand, that it was a kind of "impromptu" defence; but that in the case of steel shot or shell driven from the Whitworth hexagonal, or Armstrong 110-pounder, these chains would withstand its concussion, cannot be for a moment believed. The law of continuity of substance forbids such a theory; for, granting the chain netting to be formed of (n) links, then, if one of the series of (n) were destroyed, the law of continuity would perish, and therefore the defensive force. Again, being open, the bursting charges of shells would readily penetrate, even supposing the fragment of the shell to fall outside the ship.

In America it was discovered nineteen years ago that one-fourth inch iron would withstand cast iron shell, and of course, then, chains of say three-fourth inch would act even better; but we know that the "Warrior" target of four one-half inch rolled iron plate is no defence against steel shells; neither did the "Agincourt" target, five one-half inch, withstand the immense impact of the Mackay Gun; and it is highly probable that six or seven inches of iron would offer but slight resistance to these improved pieces of ordnance. What we *really* want, in my opinion, is a resisting substance *outside* the armour plating, for we know that the slightest thickness of an elastic medium increases visibly the resistance. The Rev. Professor Haughton, M. D., F. R. S., has shown in his Table, in connexion with armour-plated frigates, that the value of ϵ^2, the square of the dynamical coefficient of elasticity produced by the collision of bodies, is not constant, but diminishes according to some unknown law, as the velocity of the collision increases, thus :—

Steel falling on iron with a velocity of 16 feet per sec.,
The value of $\epsilon^2 = 0{\cdot}2952$;

but when the velocity increased to 40 feet per sec.,
The value of ϵ^2 *diminished* to $0{\cdot}2245$.†

Hence it is apparent that, in rifled guns, the greater the initial velocity, the less the value of rebound. In order to break the force thus augmented, some intervening substance should, I think, be substituted. Cork steeped in some alkali might be beneficial, as the lightness of the cork and its known elastic force, with its imperviousness to flame, would render it of much advantage in deadening the force of impact. Soft metal all along has been more successful than hard,—rigidity of substance being, it would seem, of rather detrimental tendency. In America cotton bales are used with much advantage, being placed as we place our hammocks round the gunwales,—their elastic force retarding the velocity, and therefore decreasing the force of concussion.

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* See "Notes and Queries," August, 1862.

† These experiments were made by dropping spherical balls of steel, iron, and brass, 2¼ in. diam., and measuring the height of the rebound : in this instance the weight was merely influenced by gravity.

APPENDIX TO THE FOREGOING PAPER.

EXTRACTS FROM THE REPORT OF THE ORDNANCE COMMITTEE OF THE HONORABLE HOUSE OF COMMONS, 1864.

Examination of Captain the Hon. Arthur Cochrane, R. N., H. M. S. "Warrior."

Quest. (2237).—Which is the most efficient weapon against an iron-plated ship, at short range—the Armstrong 110-pounder, or the old 68 pounder?

Ans.—I have understood, there is no doubt, that the 68-pounder, at short ranges, having a higher initial velocity, would be the more damaging of the two.

Quest. (2240).—Do you suppose that in action these sights (the Armstrong) could be easily brought into action?

Ans.—No; and when at sea with the squadron, last summer, we had to abstain from firing, even when firing slowly, on account of the dense smoke caused by the Armstrong guns, which created more smoke, and of a worse character, than all the rest of the guns.

Colonel W. B. Gardiner, R. A.

Quest. (by the Right Hon. W. Monsell, Chairman).—Were you present at the experiments which were tried, both in November and again very recently, with the Armstrong and Whitworth guns against the iron target?

Ans.—Yes; I was.

Quest.—What was the impression produced upon your mind with regard to the power of penetrating with the Armstrong? Which of the two guns was the more successful on these two occasions?

Ans.—I think, as regards the Warrior target, the Whitworth was by far the more successful. I know the Whitworth got through, and the other did not; that was at a range of 800 yards.

Captain A. T. Blakely, R. A.

Quest.—What is the armament of "La Gloire?"

Ans.—She has 6½ inch rifled guns, of a weight of 5 tons.

Quest.—What is the weight of the shot?

Ans.—The guns throw bolts of 99 lbs.

Quest.—Do you think the Armstrong 110-pounder, at 400 yards, would have the same effect on "La Gloire" as a French gun?

Ans.—I think not.

Quest.—Then you think the French guns are superior to the Armstrong gun?

Ans.—I am sure of it.

The weight of the Armstrong 110-pounder is 83 cwt.
,, the old 68-pounder, 95 cwt.
Whitworth 12-pounder (breech-loader), 3½ diameters:—
Weight of shot, 14$\frac{58}{100}$ lbs.
Initial velocity, 121 feet per sec.

By multiplying the weight of the shot by the square of the velocity, the result is 22,813,000 lbs. work done.

Comparison between the "Royal George" and "Glatton."

H. M. S. "Royal George," 78 Guns.	H.M.S. "Glatton" (iron-cased), Battery, 14 Guns.
Tonnage, 2616.	Tonnage, 1535.
Speed, 9·375 knots.	Speed, 4·5 knots.
Length between perpendiculars, 205 ft. 7 in.	Length between perpendiculars, 172 ft. 6 in.
Breadth, extreme, 54 ft. 6½ in.	Breadth, extreme, 45 ft. 2½ in.
Draught forward, 22 ft. 10 in.	Draught forward, 8 ft. 4 in.
,, aft, 23 ft. 10 in.	,, aft, 8 ft. 8 in.
Displacement, 4110.	Displacement, 1640.
Rate in knots per hour, 10·397.	Rate in knots, 14·539.
Length to breadth, 3·77.	
Nominal horse power, 400.	Nominal horse power, 150.
Speed, ^{3} × mid. sec. indicated power, 543·5.	Ditto, 49·8.
Speed, ^{3} × displacement ⅔, indic. power. 1·332.	Ditto, 18·3.

The greatest sea speed yet obtained is that of the Kingstown and Holyhead R. M. S. "Connaught," 2056 tons, B. M.; length, 348⅝ feet; 17·797 knots (mean) = 20·502 statute miles; nominal horse power, 720; indicated horse power, 4200.

Result of official Trial of H. M. Armour-cased Steam Sloop, "Enterprise" (designed by Mr. Reed, Constructor of the Royal Navy).

Tonnage.	Horse Power.	Guns.	Draught forward.	Draught aft.
990	160	4	11 ft. 10 in.	15 ft. 8 in.

FULL BOILER POWER.
Speed at measured Mile.

	Time.		Revol. Engines.	Speed. Knots.	Pressure Steam.	Vacuum.	Revol. Screw.
	m.	s.			lbs.		
First run, ...	7	40	98	7·826	23½	26	56
Second run, . . .	5	13	—	19·027	22½	26	99
Third run, ...	6	32	98	7·265	22	26½	,,
Fourth run, ...	5	3	100	11·881	23	27	,,
Fifth run, ...	7	26	97	8·072	22	26½	,,
Sixth run, ...	5	8	100	11·681	22½	26¾	,,

Taking the first of the above runs, we get—

First means, . . .	9·913	9·982	9·923	9·976	9·880	
Second means, . . .	9·880	9·952	9·949	9·928	—	

giving the true mean speed of the ship 9·227 knots, or about 10 statute mile per hour.

HALF BOILER POWER.

Speed at measured Mile.

	Time.		Speed.	Revol. Engine.	Press. Steam.	Vacuum.
	m.	s.			lbs.	
First run, ...	6	27	8·022	80	19	26
Second run, ...	8	54	9·363	81	19	26½
Third run, ...	8	56	6·716	81	19	26
Fourth run, ...	6	19	9·499	82	19	26½

Average speed at half boiler power, 8·105 knots.
In all these runs the force of wind was 5.

STEERING QUALITIES.

Angle of Rudder.	Time of Full Circle.			
Degrees.	m.	s.		
30	4	14	Port,	full speed.
29	4	18	Starboard,	
27	4	3	Port,	half speed.
28	4	37	Starboard,	